Exploring Gaming Mechanisms to Enhance Knowledge Acquisition in Virtual Worlds

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ABSTRACT

3D environments are very popular among gamers and ever more used for simulations and serious games. The educational value of setting an adventure/simulation in a Virtual World (VW) is significant, in particular when training a workforce in performing dangerous/special tasks. However, when it comes to the exploration of a world to learn from it - as it happens in several real-life experiences - there is the risk that a lot of "knowledge in the world" is wasted because of a lack of appropriate guidance and the difficulty of providing more in-depth information about some items without interrupting the flow of the game.

This paper discusses a Virtual Reality (VR) environment - aimed at promoting a meaningful interaction with artistic heritage - that has been enhanced with embedded microGames (mGs). mGs challenge the player to discover/investigate historical/artistic details related to a reconstructed area and virtually interact with pieces of the heritage in their context. mGs can be thought of as sort of 1-level links in the "hypertext" represented by the 3D environment where the player lives her/his cultural adventure. Preliminary informal tests have suggested that the approach is valid and also provided some guidelines about how to properly and smoothly integrate mGs in a 3D environment, which is an important requirement in order not to startle/distract the player.

Categories and Subject Descriptors

D.3 [**Computers and Education**]: Computer Uses in Education - Distance learning; Computer and Information Science Education.

General Terms

Human Factors, Design, Experimentation, Performance.

Keywords

Serious Games, Virtual Heritage, 3D reconstruction.

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1. INTRODUCTION

Games have always been an important aspect of human life, also having a meaningful impact on education. However, their design has to be careful, in order to support real knowledge acquisition. Several games have little, if any, educational value or may be misused. These concerns are strengthened in the case of the video-games, that provide meaningful additional features (e.g. possibility of using large databases and of exploiting interactivity, immersive-ness and personalization [1]), but may also create dependency and promote/induce dangerous behaviors [2], [3].

State of the art computer games typically involve a 3D environment into which the user lives exciting experiences related to an adventure, a historical fact, a sport. Educational games exploit state of the art computing and networking technologies to provide an educational value inside an entertainment framework. However, it is not easy to combine real education and entertainment. This is testified by the fact that it is very rare to find successful commercial games that promote knowledge/skill acquisition in a particular field [4]. On the other hand, educational games tend to be perceived as boring, at least by the general public [5].

Trivial to say, entertainment is a key factor to success. Even the recent successful cognition-activity supporting games (e.g. Nintendo [6]) are perceived more as a challenge rather than an exercise. In this view, we intend to exploit paradigms and models of the state of art games and upgrade them in order to make them suited to deliver educational value. In other words, our idea is to enhance existing game concepts rather than designing educational exercises with a game aspect (e.g. score, penalties, lives). This requires finding appropriate mechanisms that are to be seamlessly embedded in the paradigms that appeal a wide audience. This is fundamental in particular if we do not aim at a specific category of users (e.g. learners that may be motivated to play a game independent of its appeal) but we strive to promote a knowledge item (e.g. art history, biology, botanic, etc.) to the general public (e.g. in a life-long learning perspective, which is an important objective of current information society's policies). In this perspective, we are interested in exploiting 3d Virtual Reality (VR) environments, that are very popular, in particular among the youngsters. Necessary steps in the design of a VR educational game include the definition of the contents, plot and rules (e.g. concerning assignment of the score). Beside this, we have studied further mechanisms that could be inserted in the 3D environment so to make it more appropriate to deliver educational contents.

In this paper, we investigate in detail one of such mechanisms: the exploitation of 2D inserts (e.g. games, animations) in a 3D virtual world. The 2D-3D interaction has been introduced in augmented reality environments [7] and has been further developed to identify the dimensional characteristics of a task [8]. The use of interactive 2D inserts is applied in educational games, because it makes all learning 2D games exist within a consistent virtual world, positioning learning as a natural outcome of engagement with the world [9]; we consider it as a powerful idea, as it joins the spatial knowledge acquisition potential of 3D virtual worlds with the possibility of getting more in depth information on a specific item that has been found/suggested in the 3D world. This can be particularly meaningful in the field of the cultural heritage. For instance, the player could explore a faithfully reconstructed place (e.g. a city, a region) and live there some information-rich, contextualized experiences through which she/he could get more in on an item somehow available in the territory. These experiences would be implemented through small 2D inserts. The whole should be perceived as a compelling, exciting and culturally meaningful story/adventure.

This concept can be thought of as the "digital analogy" of a visit of a city/region (which is typically enhanced by visits at museums, galleries, churches and other important buildings and/or memory places), which is the traditional way through which a number of people - from common tourists to specialized scholars - have developed a lot of knowledge about history, art, foreign people and geography.

Based on this idea, we are developing the Travel in Europe (TiE) project, which aims at implementing an innovative mean to promote and divulgate the heritage. TiE is developing an online environment – it will be accessible through common web-browsers - where users will live challenging and compelling experiences by interacting with virtual representations of the European heritage. The project exploits the concept of travel, which is both engaging by itself and also supports geographic contextualization.

A player of "Travel in Europe" (TiE) will typically accomplish a mission (sort of treasure-hunt game) by visiting some cities spread in the Europe map. In each city, the player will gain scores by facing some specific trials. Trial games – they are implemented as small, simple 2D games - concern the local artistic heritage and are contextualized. For instance, a game concerning Van Cleve's "Adoration of the Magi" triptych will be played in the 3D reconstruction of the San Donato church in Genoa's historical center, where the picture is conserved.

These include their advantages/disadvantages and the analysis of the features/requirements that can make them useful and usable: in this paper we intend to explore some issues related to the educational and entertainment aspects and value of inserting 2D spots in 3D contexts.

2. RELATED WORKS

Research work argues that computer games are an engaging medium for learning since they can stimulate cognitive processes as reading explicit and implicit information, deductive and inductive reasoning, problem solving, and making inferences from information displayed across a number of screens [10]. These results have been achieved through a numbers of games that either have a direct educational value or provide knowledge/stimulate skills as a side-effect [4].

The idea of using networked Virtual Worlds (VWs) as educational medium started in nineties (e.g. ExploreNet Experiment [11]). Today, with the increasing availability of PCs and wide-band connections, VWs can reach potentially enormous communities of would-be learners. Some virtual learning worlds (e.g active worlds learning environment [12]) tend to mirror a classroom environment [13]. The social interaction enabled by VWs can contribute to improve engagement, participation and maintain learner's interest. Indeed, students perceive more satisfaction in a course if they are actively involved in it and they are allowed to develop relationship with other learners. In this perspective, an important opportunity is given by the current successful trend of Massively Multiplayer Online Game (MMOGs), that have developed, for entertainment purposes, powerful tools that may be exploited to provide knowledge to thousands of players [14].

Second Life (SL) [15] is a 3D virtual environment created by Linden Labs, which has gained wide popularity, in particular on the mass-media. SL is organized as a set of VWs, structured as islands, where user avatars live a variety of experiences. Several islands have been built and used for distance education, where students can attend parts of courses also at university level [16]. The OpenSIM project is attempting to develop a similar VW environment that can be run on any server and would be free of any "for-profit" entity's control [17]. The approach of TiE is more specific, as it targets fruition of real cultural heritage. Coherently TiE provides specific mechanisms, procedures and tools (they are described in the next sections) to support building culturally valid and realistic user experiences in an entertainment context.

A specific computer science research field - the Serious Gaming [4], [18] - has recently developed in order to exploit the potential of games in practical education. According to the constructivist approach [19], learning depends on the active engagement of the subject that learns, and on her/his ability to construct knowledge and understanding on the basis of her/his interaction with the environment.

Several advanced computing technologies have been used for games. They are substantially related to 3D visualization, and range, for instance, from object modeling to real-time computation, from Virtual Humans to artificial intelligence. Examining the brain's electrical activity, Kahana and others [2] have shown from a neuroscientific point of view that computer games engage spatial learning [20]. This is particularly true for 3D games, where the reconstructed environment allows a more complete and immersive experience of the space and context, at least in principle. The player can get more familiarity with the surrounding space, through exploration that may be spurred by a game by proposing to the player the accomplishment of challenging missions. Missions and tasks may spur the sense of site and critical reasoning, also through social interaction with other players.

However, there are still educational aspects that have to be further studied in order to better exploit the potential of computer technologies for the education. A significant issue concerns the risk that the player gets easily lost in the knowledge space of the

simulated environment. This requires a meaningful, compelling plot and proper guidance (e.g. through spatial landmarks [21]), that can drive the player through a suited (e.g. not dispersive) knowledge path or, in a more constructivistic approach, can effectively support her/him in her/his free exploration. But also other game mechanisms need to be defined and implemented in order to achieve effective and aware learning. The mechanisms should significantly enrich the environment (e.g. by supporting orientation, providing more detailed information, etc.), and should be well integrated in the game logic and aesthetic (they should not appear as "boring educational add-ons"). In the end, the environment has to be stimulating. Some such mechanisms have already been presented in the literature and in commercial games. These include the criteria for the evaluation of player enjoyment (the Flow Channel theory) [22] and the multimodal environment interaction [23].

3. TRAVEL IN EUROPE ENVIRONMENT

The main objective of TiE consists in the design and development of an online environment that supports users in perform adventures similar to state of the art videogames, but provide mechanisms and patterns of use that stimulate knowledge acquisition and promote an effective fruition/understanding of the heritage. Having a full environment is a significant added-value, since it will not mean developing a single game, but an extensible platform on the top of which a number of different games may be built, each one of them being able to exploit the educational/cultural features, mechanisms and functions provided by the TiE environment. Sample features include accurate 3D reconstructions and mGs that allow players to manipulate digital representations of the heritage. As a meaningful example of the potentialities of the TiE environment, the project is building a sample game, a sort of a cultural treasure-hunting game to be performed among a number of virtual reconstructions of European cities.

In order to achieve the above mentioned goals, the TiE architecture is based on a game engine, with Massive Multiplayer Online Game (MMOG) facilities that provide a wide and pleasant access, plus ad-hoc designed modules. These modules include: the algorithms for efficient collection of architectonic urban contents, and efficient implementation of high-quality, realistic 3D models based on such contents; the TiE cultural game mechanisms and patterns; the algorithm to implement realistic 3D reconstructions of monuments; the cultural mG Templates.

3.1 TiE Virtual Worlds

TiE involves reconstructing a number of culturally-relevant cities and villages throughout the whole Europe. This is a huge, long-term effort that required fixing some fundamental principles since the design phase.

A 3D reconstruction of a city or a region for education/cultural aims within an interactive environment is a process that requires a careful trade-off between the models' photorealism (in order to provide a highly impressive and culturally correct and meaningful experience) and the models' weight (in order to allow interactive real-time online exploration) and complexity.

The first term of the trade-off stresses the importance of having high detailed 3D reconstructions in order to realize a sound reconstruction of the heritage.

The second term highlights the performance problems that the TiE online environment has to overcome to provide users with a playable and enjoyable system. Moreover, complex systems are costly to implement both for the 3D modeling aspect and for the need to create proper textures (which requires taking pictures, rectifying and equalizing them, and composing in the final textures that can be managed by the final graphic engine).

In a highly interactive system, such as a 3D exploration/game, the details of the reconstructed environment are not fundamental to display, as the player moves rapidly there. However, in the case of a cultural heritage game, the player, playing the role of a sort of art detective, has also to carefully examine also the particulars, where relevant.

In order to meet the above stated requirements, we have designed the reconstruction of each covered place (e.g. a city or several areas inside a city) as it follows:

- The 3D model is completely geo-referenced. The ground is elevated from a local 3D vectorial map. So, the placement of the buildings and their borders are precise. This allows compatibility/portability to various Geographic Information Systems (GISs) and expansibility of the system (i.e. possibility of upgrading buildings with their actual textures – see also the next bullets).
- In each covered area, a few Point-Of-Interests (POIs) are implemented. These are rigorous, high-detail reconstructions of a building. We use this approach for culturally meaningful buildings. For instance, the cathedral, the theater, a Renaissance palace.
- The textures for all the rest of the palaces are built dynamically by the TiE system using a statistical template-based algorithm [24]. Since several zones within a city are typically characterized by relatively homogeneous buildings (one or few more "styles"), the idea is to exploit a statistical description of the architectonic parameters and to build the buildings' virtual models accordingly, using a limited set of parametric building models and of textures that are instances of architectonic features representative of that area.

In this way, on the one hand the effort to cover extended urban areas is reasonably manageable (in any case, the content creator has the choice of defining the number of buildings' models, textures and parameters for the reconstruction), on the other hand, the reconstructed environment allows users to live experiences somehow similar to a real visit of a city, where a visitor typically perceives the feeling of being in a precise place but usually does not perceive/remember the particulars of each distinct building. We refer to this approach as based on an architectonic-style likelihood principle.

Moreover, the buildings that are particularly meaningful from a cultural point of view are reconstructed with high detail and with their own specific real textures (i.e. not statistically defined). These buildings may be the subject of a more attentive analysis by the player, as suggested by the game plot and rules.

The above mentioned approach allows an efficient set-up of an extended urban 3D environment where cultural virtual experiences are made possible. Of course, plots and game rules are important aspects to drive the user experience and support a proper fruition of the reconstructed heritage.

But, beside these aspects, that are external, superimposed to the environment (they define the logic of a particular game built on top of that environment), we are interested to identify and analyze mechanisms that may be embedded inside the 3d environment itself, so to enrich it and further increase its educational value (i.e. give more detail of particulars, provide more in-depth information, present related historical facts) and, possibly, the entertainment of the users.

The proposal of the mGs, that we present and discuss in the following, intends to be a possible answer to this search.

3.2 MicroGames

mGs are simple, short games that focus the player's attention on a particular item that she/he finds during her/his exploration of the 3D world. mGs are typically taken from well known game models, such as Puzzle, MemoryGame, FindTheWrongDetails. The idea, in fact, is that they should be immediate to play, so that the player can focus on the contents rather than on learning how to play.

In order to re-use code and provide consistent and homogeneous interaction modalities (that can be quickly and easily learned by the player and then used several times), we have defined a library of mG Templates. Every mG is an instance of one of such templates. We broadly divide game templates in three categories, according to the cognitive skills they mostly involve: observation games, reflection games, and action videogames.

3.2.1 Observation games

These games privilege the sight as a sense to investigate and explore the local environment. In general, these games tend to exploit the "knowledge in the world" in order to develop the cognition activity [13], [14], [25]. They aim to stimulate spatial processing skills. Such skills are important in cognitive development since they allow an individual to create meaning by manipulating visual images [26] [10].

3.2.2 Reflection games

These games tend to favor reflection, discussion among team members, analysis of questions and possible answers considering clues available in the neighborhood and concepts learned previously during the game.

3.2.3 Arcade videogames

These games stimulate similar skills as observation games. Their specificity lies in the animated graphics and engaging interaction, which helps to create a convincing and pleasant experience. They stimulate fantasy and evoke images and atmospheres that can be used to convey educational messages which are easily memorized by players.

To give a concrete idea, samples of mG templates that have been developed in TiE include:

3.2.4 Puzzle (Observation)

The player has to compose the Reconstruct an image (e.g. a picture, a palace, etc.) whose elements appear randomly shuffled in the screen. The model for reconstructing the image is not on paper: it is in the virtual reality (the player may have seen the relevant item during her/his exploration or may be playing just in front of that reconstruction, or may be spurred to search for it throughout the city). The image to be reconstructed could also be synthetical (e.g. a map of the trade traffics of the city in ancient times). The game itself stimulates several skills, among which the ability to identify geometrical patterns, recognize colors and associate similar areas.

3.2.5 Quiz (Reflection)

This is a simple multiple-choice question (or list of questions). The question is generally tied with the place where it is made (e.g. a question at the Venice's Arsenal concerns the interpretation of a Dante's piece of the Divina Commedia where the work at the Venice's Arsenal is described). Sample quizzes include: historical quizzes, guessing games, local dialect/language. Typical player skills include critical reasoning and evaluation of alternatives (we suggest that the quizzes are not related to the previous cultural knowledge of the player but to items that the player may learn/discover from her/his exploration of the reconstructed world, and of previously played mGs. In any case, the questions are prepared by the content author who is completely free to choose). A version with images instead of written questions/answers is always available (VisualQuiz). Synthetic virtual characters (Virtual Humans enabled by Artificial Intelligence) that represent local people may be contacted by the player to ask for the meaning of a local word and other suggestions. Social interaction is also encouraged since the player may ask help to other players' avatars, sharing score with them.

3.2.6 CatchIt (Arcade).

A typical local character is placed in a higher position (e.g. a balcony, a bridge) and drops some objects: the player's avatar stands below and has to catch the right objects (e.g. food/paintings/clothes related to the specific place/area) and avoid the spurious ones. The game is ever more dynamic and requires that the player be attentive, quickly recognize items and understand their meaning.

A fundamental feature of mG templates is the fact that they are parametric. Every mG instance consists of generic software (one for each template) and an instance-specific XML configuration file that provides the values – defined by the content author – of the parametric features of that template. The configuration file is easily editable by the content author, who is thus able to build simple games without any knowledge of the software. Configurability is important in order to support code-reuse and allow authors to easily instantiate services for their applications, according to their actual needs. Instantiation parameters involve both contents (i.e. text, images, difficulty levels, timings, etc.) and appearance (i.e. buttons, font colors, etc.). Some important parameters concern the learning mechanisms. Sample possibilities include:

- Weighting of several parameters in the computation of the score (e.g. time elapsed, number of penalties, number of requested helps, number of 'moves' to arrive to the solution). For instance, an author may reward precision (number of

moves) rather than speed to arrive to a solution, to promote an accurate, rather than quick, analysis of the item/issue.

- Availability of introduction and conclusion texts, that may be useful to complement with verbal knowledge the hands-on experience of the player in the mG.
- Regulation of the feedback (e.g. giving or not the correct answers, when, with what comments).

Parameter values can also be subject to dynamic instantiation. This means that the author can specify more than one value for a given instance's parameter and the associated assignment rules (e.g. if age>70 background="img1.jpg" else background="img2.jpg"). The Adaptation module of the TiE environment, which is the responsible for keeping the player's profile, does the matching at runtime.

Beside the instantiation parameters of a mG, the content author has also to specify its display rules. These define the conditions (e.g. elapsed time, player's score and position) under which that specific mG will become available to a player. For instance, one puzzle game could appear when the player is in front of a triptych in a church, if she/he has successfully passed the previous 3 games, she/he has collected a torch to light it, and the elapsed time is below a certain threshold.

mGs contents are usually correlated to the PoI in which they are embedded. For instance, contents and themes could touch historical facts happen there, pieces of heritage preserved. There are also other linking possibilities (in any case, a mG's contents are related with the visited area/city). For instance, a mG could be triggered as a bonus, or as a help to allow the user, while playing, to collect useful information on an item, or could be one or more questions asked by a virtual character met on the way. Also, a sequence of mGs may appear at the end of a user exploration of a city as a summative challenge to test the knowledge acquired in the place.

An important issue concerns the Human-Computer Interaction (HCI) modalities. We have investigated them in preliminary studies with early prototypes of mGs, getting useful information from young people and teachers involved in workshops [19]. We highlight here the requirements for a third person point of view, with analogic-style indicators and a gamepad command console. Also, a well readable map is needed.

Concerning the appearance of the mGs (that should somehow pop-up from the virtual world), the most appreciated interaction modality is through a mobile device reconstructed in the virtual world. It would be like a palm-top computer through which the player would manage all the aspects related to the mGs. An alternative would be represented by an external interaction window, but it was generally considered as less engaging.

3.3 The Creative Toolkit

Rather than developing one single application, TiE has designed an extensible technological framework that can be used to implement a number of edutainment applications with different types of contents/adventures. These applications are based on the above presented enriched 3D environment, and can be configured on the top of it (e.g. by instantiating mG templates, adding new city models, defining game rules).

In order to make the authoring aspect accessible also to educational experts not familiar with computers, we are developing a visual Authoring Tool - namely the TiE Creative Toolkit - that supports the content author in configuring TiE games (rules that determine the plot, available worlds, etc.) and creating instances of mGs.

Using the mG Designer (that is the dedicated part of the Authoring Tool) the creator, supported by a Wizard of Oz, can instantiate one mG Template and specify its configurable parameters. This is a significant advantage of the modular design approach that we have proposed.

In this way, a creator may create games/quizzes for a given city/area, using her/his own multimedia contents, and indexing.

The possible applications, also in a user-generated contents perspective, are multiple: for instance, teachers could instantiate a set of mGs related to their lessons; keen multimedia developers could use the online framework to create a complex, compelling and realistic adventure; generic end-users, following basic rules, could experience a simple online game construction.

4. TIE GAME PROTOTYPE: GENOA CITY CENTER

The first realization from the TiE environment is a part of the Genoa historical city centre, Strada Nuova (see Figure 1), an area that contains outstanding palaces from the Renaissance and Baroque age.

Figure 1 The area (Strada Nuova) inside the Genoa city center

The player's avatar can explore the main road and the back alleys typical of Genoa city centre (see Figure 2); some icons, linked to specific PoIs (e.g. palaces, churches), trigger some mG sessions (dynamically loading contents from a database) through which the user can virtually manipulate pieces of the artistic heritage and face quizzes concerning the history of Genoa. Sample mG Templates that have been instantiated include: TextQuiz, VisualQuiz (see Figure 3), FindTheWrongDetails and FindTheMissingDetails.

Figure 2 A snapshot from the TiE 3D reconstruction of Strada Nuova in Genoa city center

Figure 3 A snapshot of a mG (VisualQuiz) about De Ferrari square in Genoa

In this work-in-progress environment we have made preliminary tests with high-school students and experts of art/history and education. The idea is to get some hints about usability and usefulness of the implemented environment, included the embedded mGs, in order to inform the further design, that is involving the implementation of the virtual environments representing 15 cities/rural areas other European countries.

Based on this analysis, we propose some indications that we tie to our experience of mGs but we believe may be well generalized to other kinds of learning/entertainment mechanisms (e.g. videos, quizzes, texts, etc.) that may be embedded in an education-oriented 3D world. Of course, the analysis is early and has no statistical value, but we consider it as a useful element for a more aware discussion on the mGs value, the way we are designing them and their integration, and on how to make the most of the potential of such insertions.

Overall, mGs have to be well embedded in the overall containing environment. This has some important implications, which we outline in the following:

- Timing. mGs should not be too long. They should be focused on a specific item.
- Every mG should have a precise educational/knowledge/skill acquisition target.
- Difficulty of the mGs has to scale with the player's performance.
- The player should have the possibility to quit games at any time.
- Score of the mGs has to be carefully tuned and be consistent with their difficulty and educational value.
- Typologies of games should be few (around 15-20), so that the player can learn easily and play quickly. But variety of instances is important to keep the player motivated and attentive.
- Games should not interrupt the player's expected flow of actions. Rather, the games should be "searched/chased". For instance, the user should have the goal to collect a special object, or reach a certain place. In this case, playing a game would be the outcome (reward) of a chase. However, some surprises, if rare and not disturbing are really welcome.
- Games are very appreciated if they are smartly proactive. Samples include bonus games and games that appear in order to help the player (e.g. allowing her/him become familiar with some items).

Several of these aspects are efficiently managed through the configurability of the templates. Dynamic adaptation is also being implemented as a consequence of this requirement. This means that, for instance, the number of pieces into which a puzzle's image is broken may depend on the actual score of the player or her/his path/performance in some previous games.

5. CONCLUSIONS AND FUTURE WORKS

3D environments are very popular among gamers and ever more used for simulation and serious games. The educational value of setting an adventure/simulation in a virtual reality world is significant, in particular when training workforce in performing dangerous/special tasks (e.g. military simulations [27]). However, when it comes to exploration of a world to learn from it, as it happens in several real-life experiences, there is the risk that a lot of "knowledge in the world" [28] is wasted because of a lack of appropriate guidance and the difficulty of providing more in-depth information about some items without interrupting the flow of the game.

In TiE, we are developing a virtual environment – it is aimed at promoting artistic heritage - that has been enhanced with embedded mGs. mGs allow the player to virtually interact with pieces of the heritage in their context and to discover/investigate some details related to that area (e.g. we use some mGs as "portals" to live a short adventure in the past times in the same place). In this way, mGs can be thought of as sort of 1-level links in the "hypertext" represented by the 3D environment where the player lives her/his cultural adventure.

Extended user tests are necessary – and already planned in the context of the project – in order to achieve an appropriate assessment of the proposed approach. However, preliminary informal tests have suggested that the approach is valid and also

allowed us to define guidelines about how to properly and smoothly integrate them in the environment, which is an important requirement in order not to startle/distract the player. Concerning the HCI modalities, interacting through the interface of a virtual device, such as a virtual reconstruction of a palmtop computer, is considered pleasant and exciting (e.g. a configuration rule of a TiE game allows the device to vibrate in the proximity of a location where a mG may be found).

The nature of the application - concerning exploration of the artistic heritage - is important for sustaining the validity of the proposed approach. In fact, it benefits from the possibility of combining spatial knowledge with in-depth historical and cultural investigation. However, the approach is general, and we believe it could be successfully adapted (e.g. with other specific types of mG templates) to other contexts as well.

As of now, most of the implemented templates are simple 2d games. However, we are also exploring other modalities of interactions - more directly integrated in the 3D world - such as questions asked by Virtual-Humans or observation games directly played in the 3D environment (e.g. finding the wrong details on a palace facade).

In general, we believe that 3D worlds represent a great opportunity for education and that a number of interaction mechanisms are to be thought and investigated in order to achieve a proper exploitation of the computer potential in this field..

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